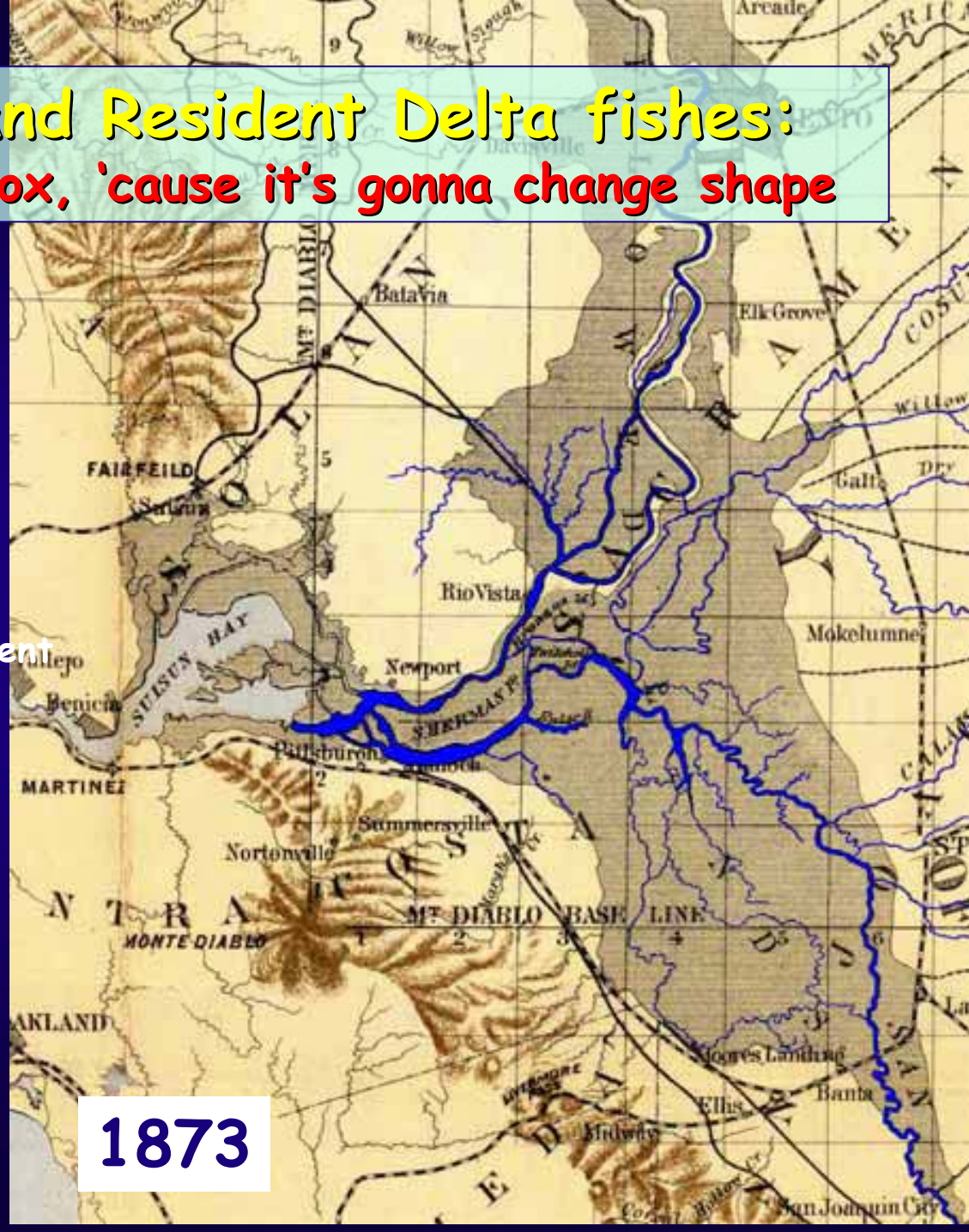


# Climate Change and Resident Delta fishes: Thinking outside-the-box, 'cause it's gonna change shape

**Bill Bennett**

Center for Watershed Sciences  
John Muir Institute of the Environment  
Bodega Marine Laboratory  
UC Davis



**1873**

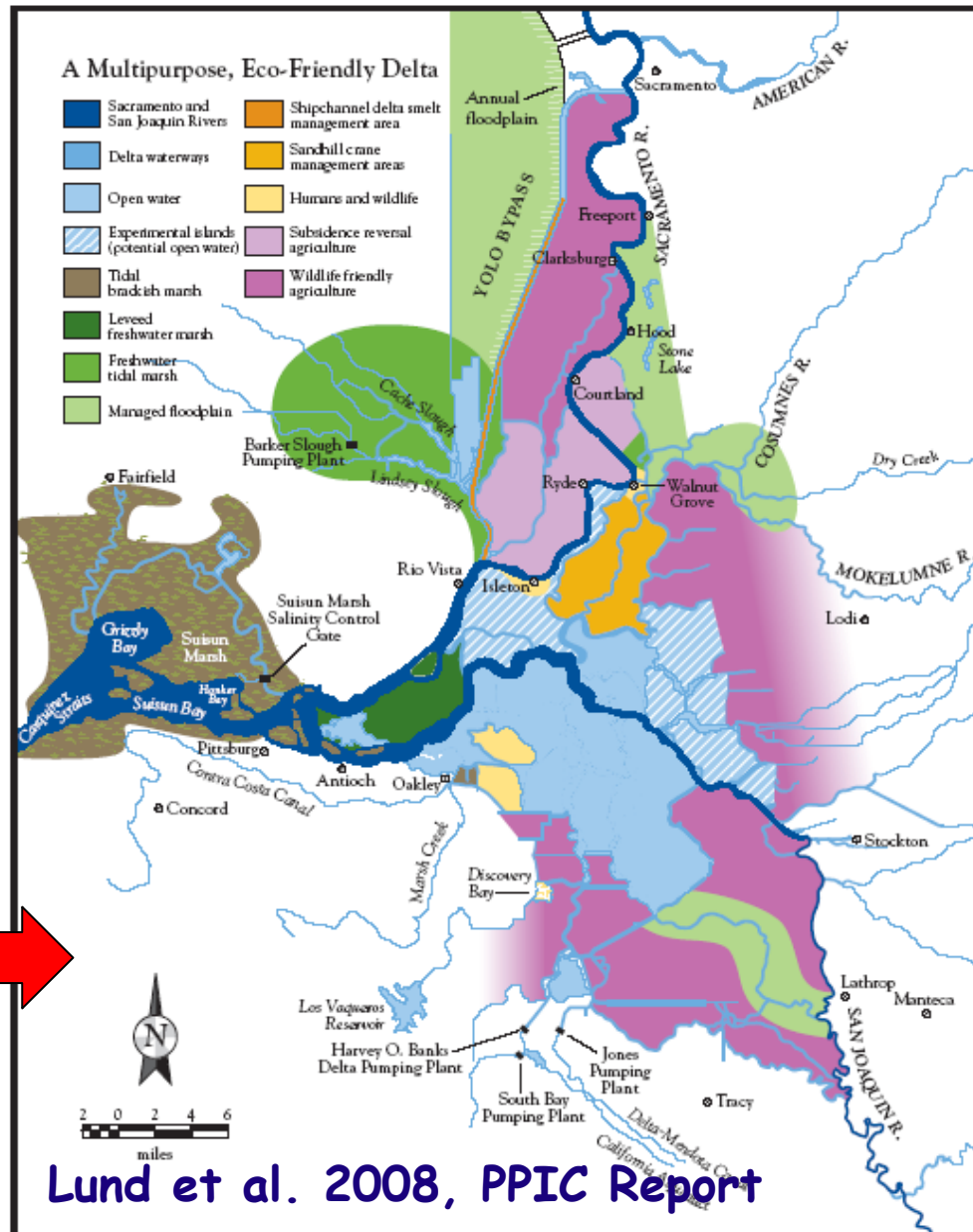
# "The Invisible Present"

J. Magnuson, 1983, Bioscience

Humans have difficulty  
perceiving ongoing change  
at large temporal and  
spatial scales.

## Anticipated Changes:

- Earlier spring runoff
- Sea level rise
- Rise in water temperature
- Food web alterations



# Striped Bass and Climate Change

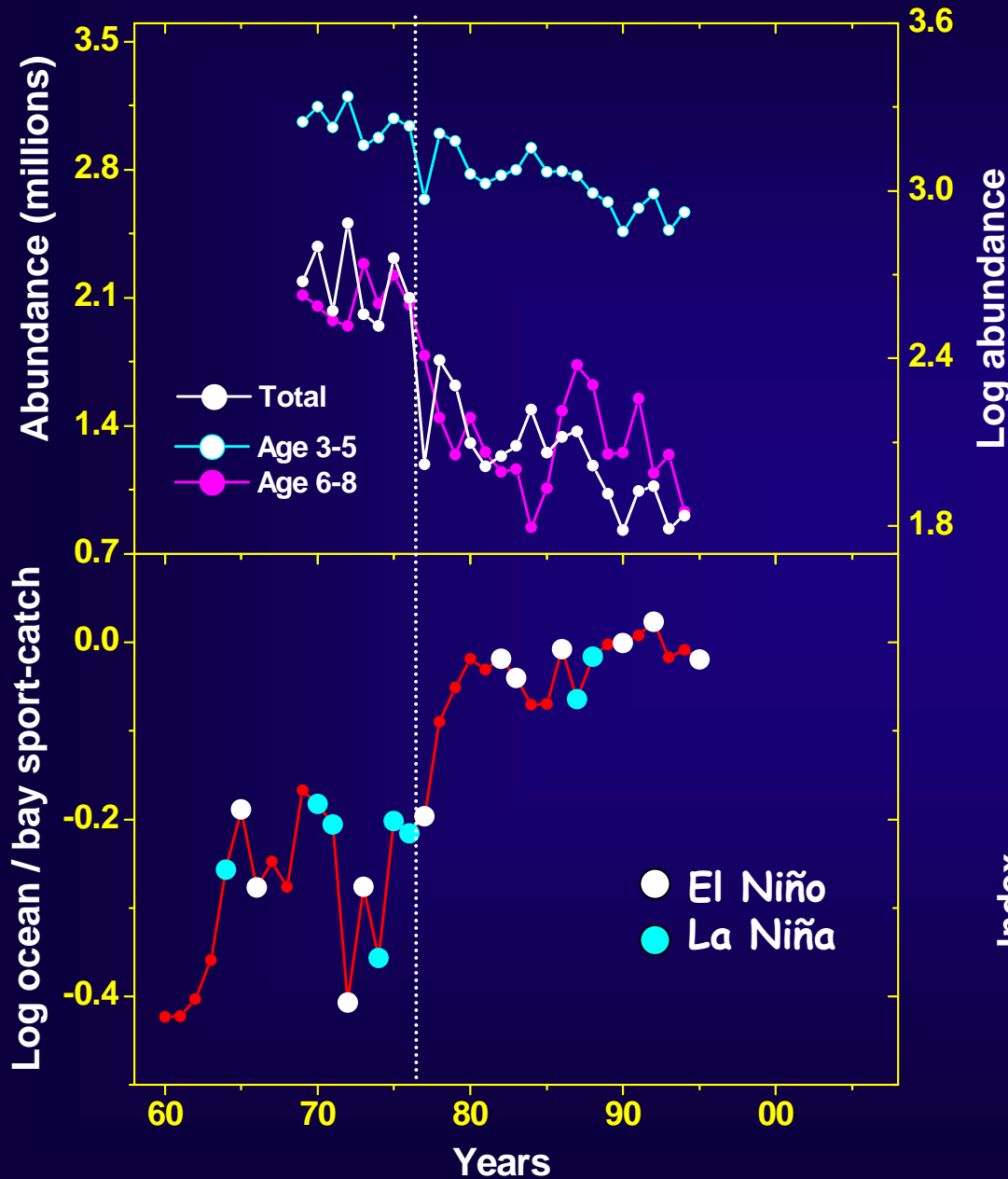


- Introduced in 1879 from Hudson River.
- Historically the most valuable fishery.
- The “Canary” before delta smelt:  
Pollution and Water Diversions
- Declined dramatically after 1977
- Decline attributed to water exports:  
entrainment of young of the year fish.
- Unlike native populations, the majority of individuals do not migrate to the ocean.

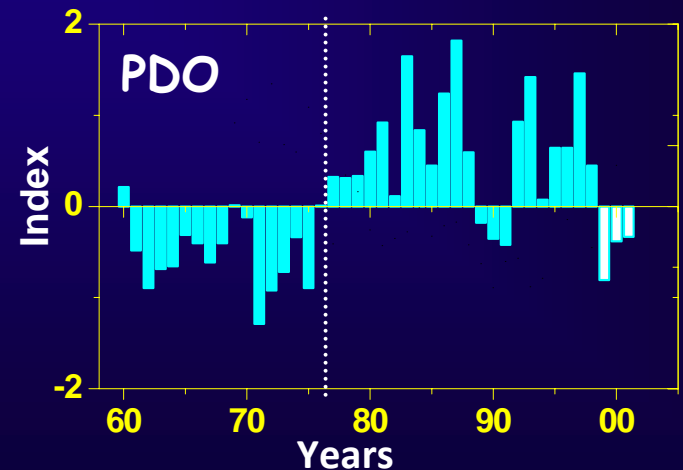
## Question:

Did a behavioral response to ocean warming  
cause the decline?

# Striped Bass Decline and Ocean Climate

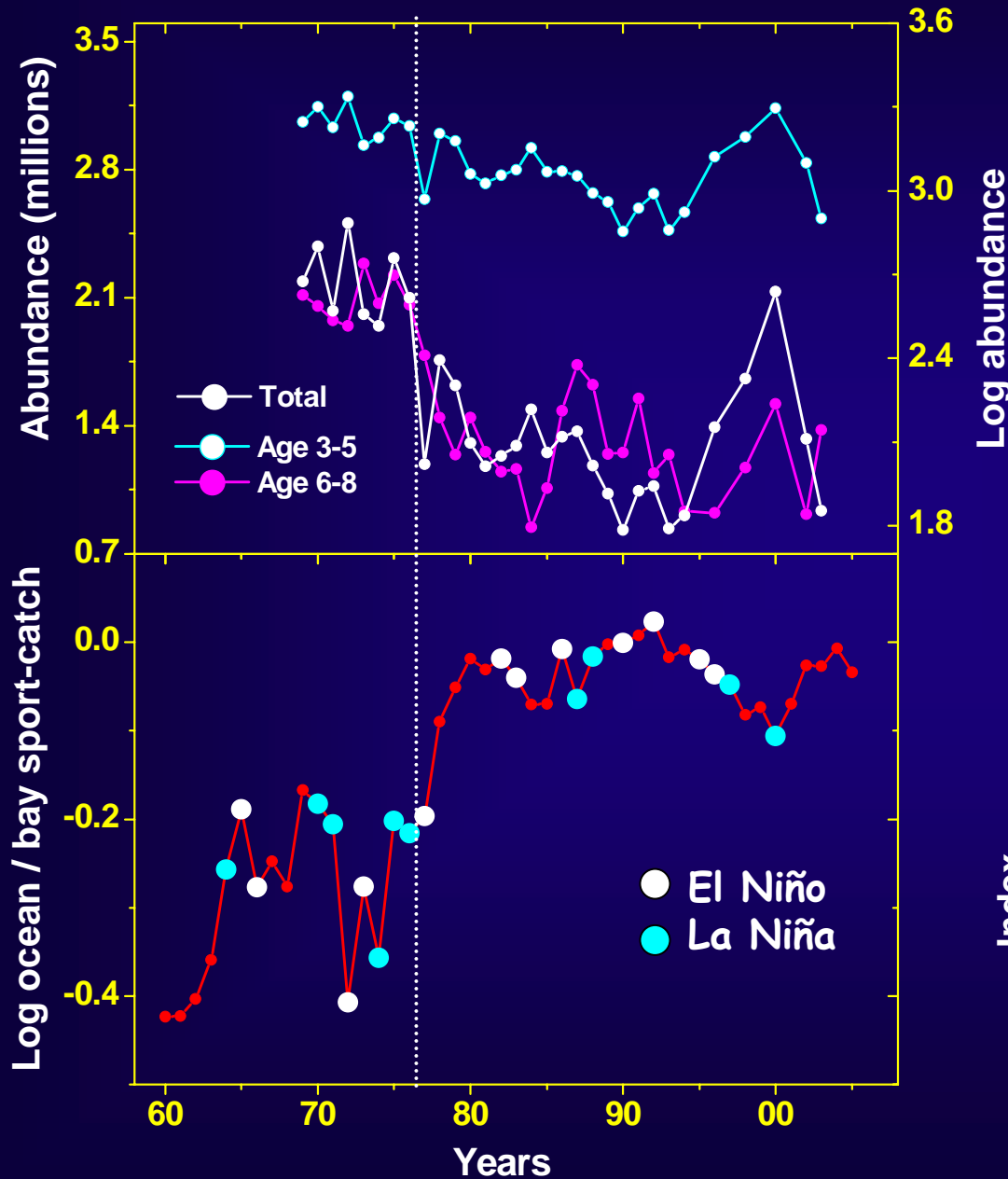


- Population declined in 1977 as PDO shifted to warm.
- Declined primarily due to loss of older fish.
- Ocean catch increased relative to the Bay after 1977.
- Population increased in late 90's as PDO shifted to cool

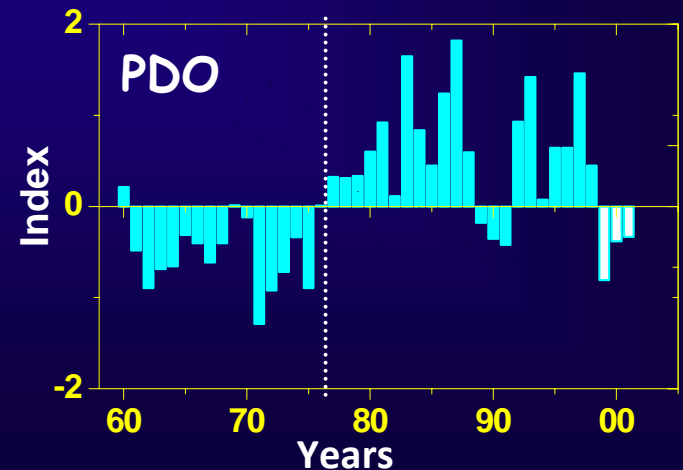




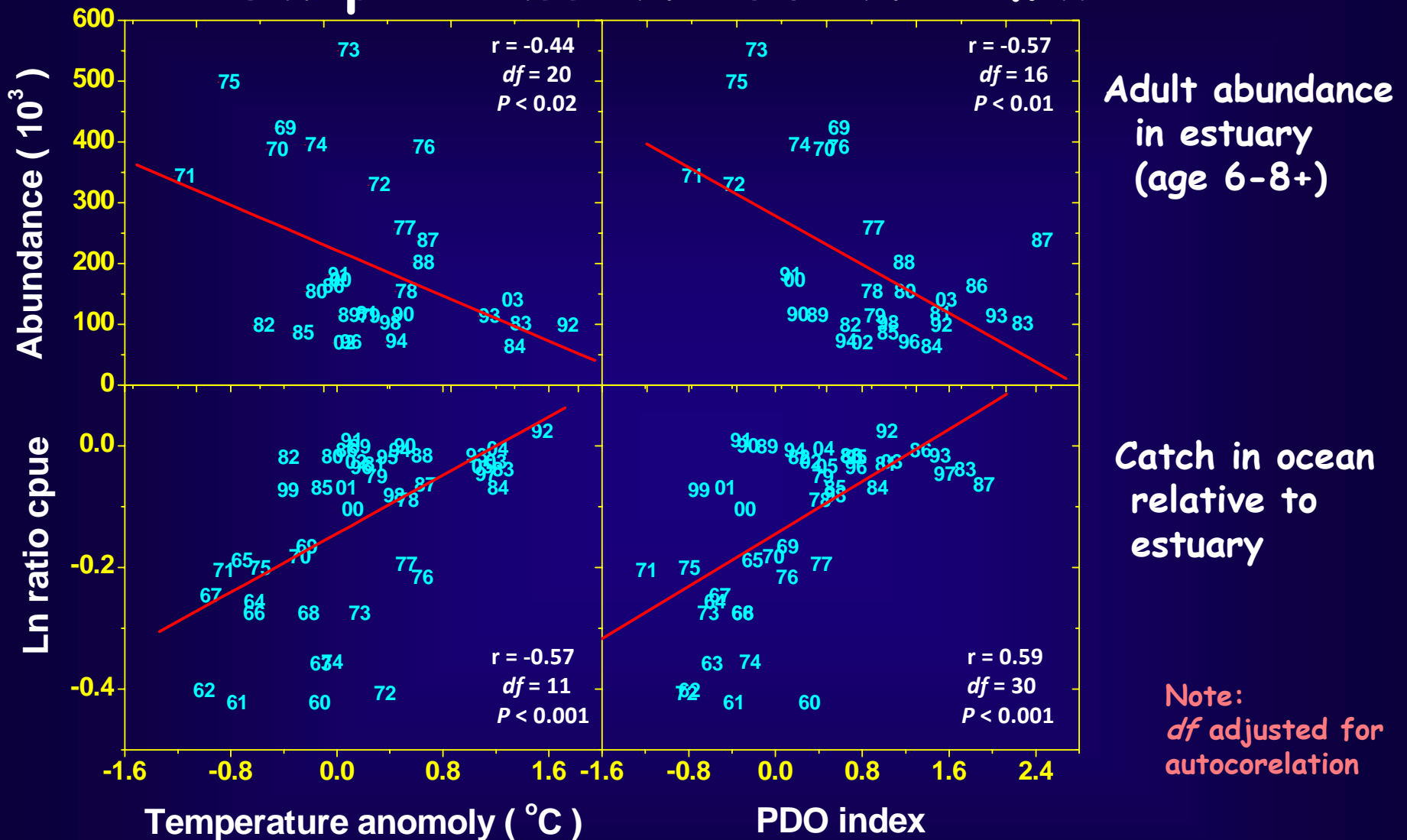
# Striped Bass Decline and Ocean Climate



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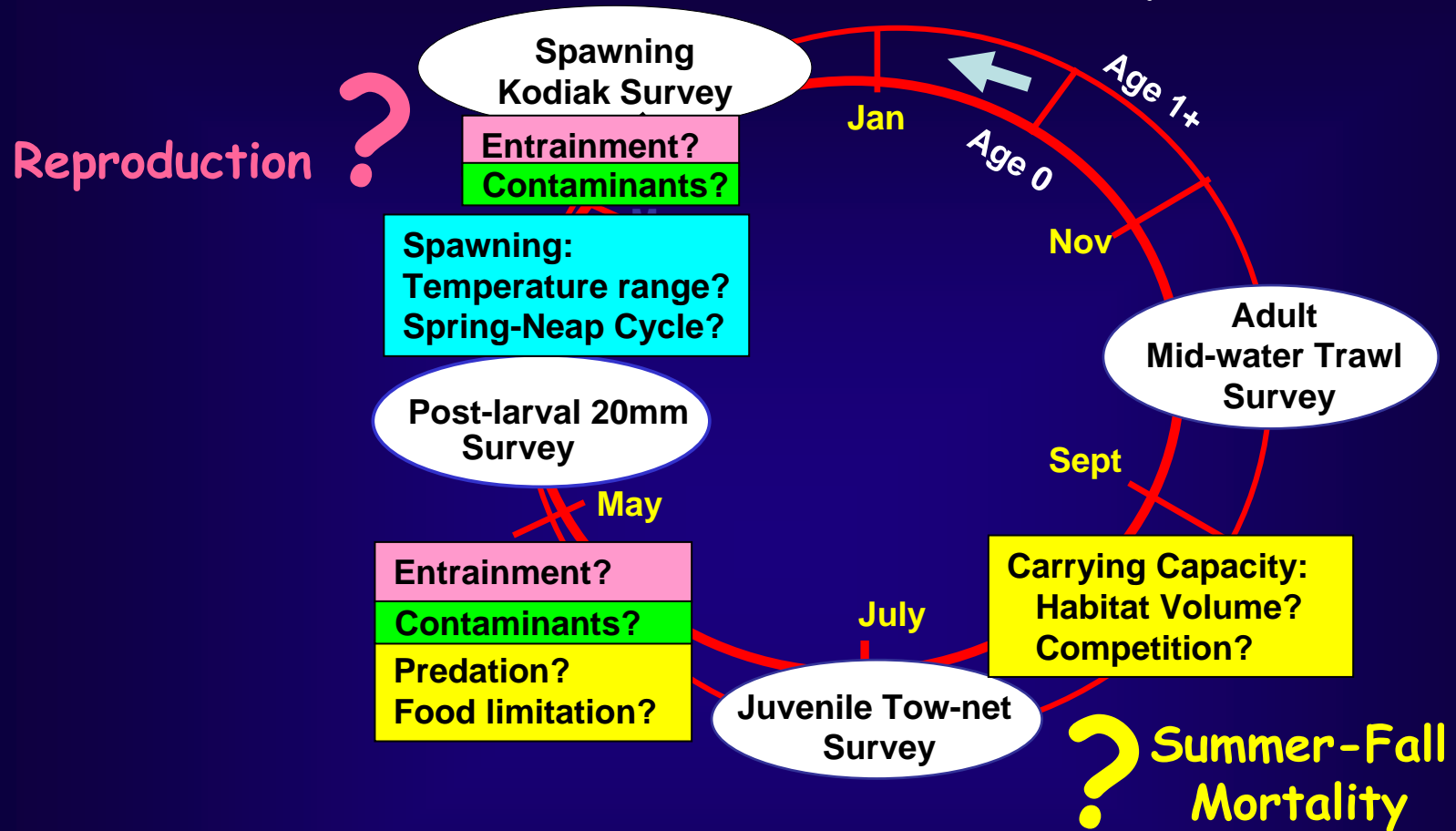


# Striped Bass and Ocean Climate



**Decline and resurgence of population caused by a direct behavioral response to climate !**

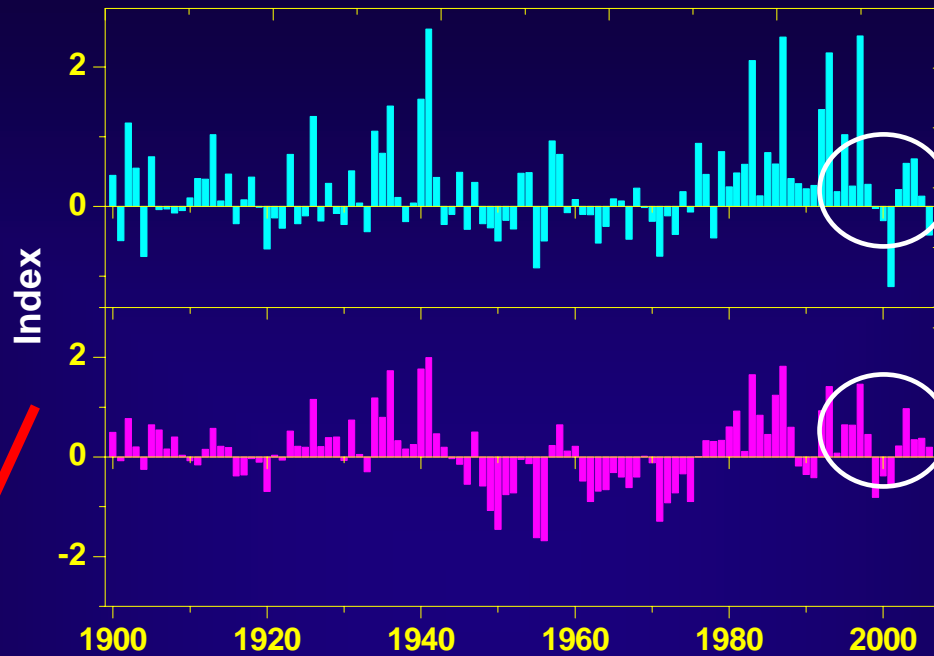
# Delta Smelt Life History



Effects at life stages typically are not discrete or mutually exclusive.  
Implications of long-term processes for short-term problems.

Bennett 2005. San Francisco Estuary & Watershed Science

## Pacific Decadal Oscillation, PDO



HOT SUMMERS - +PDO

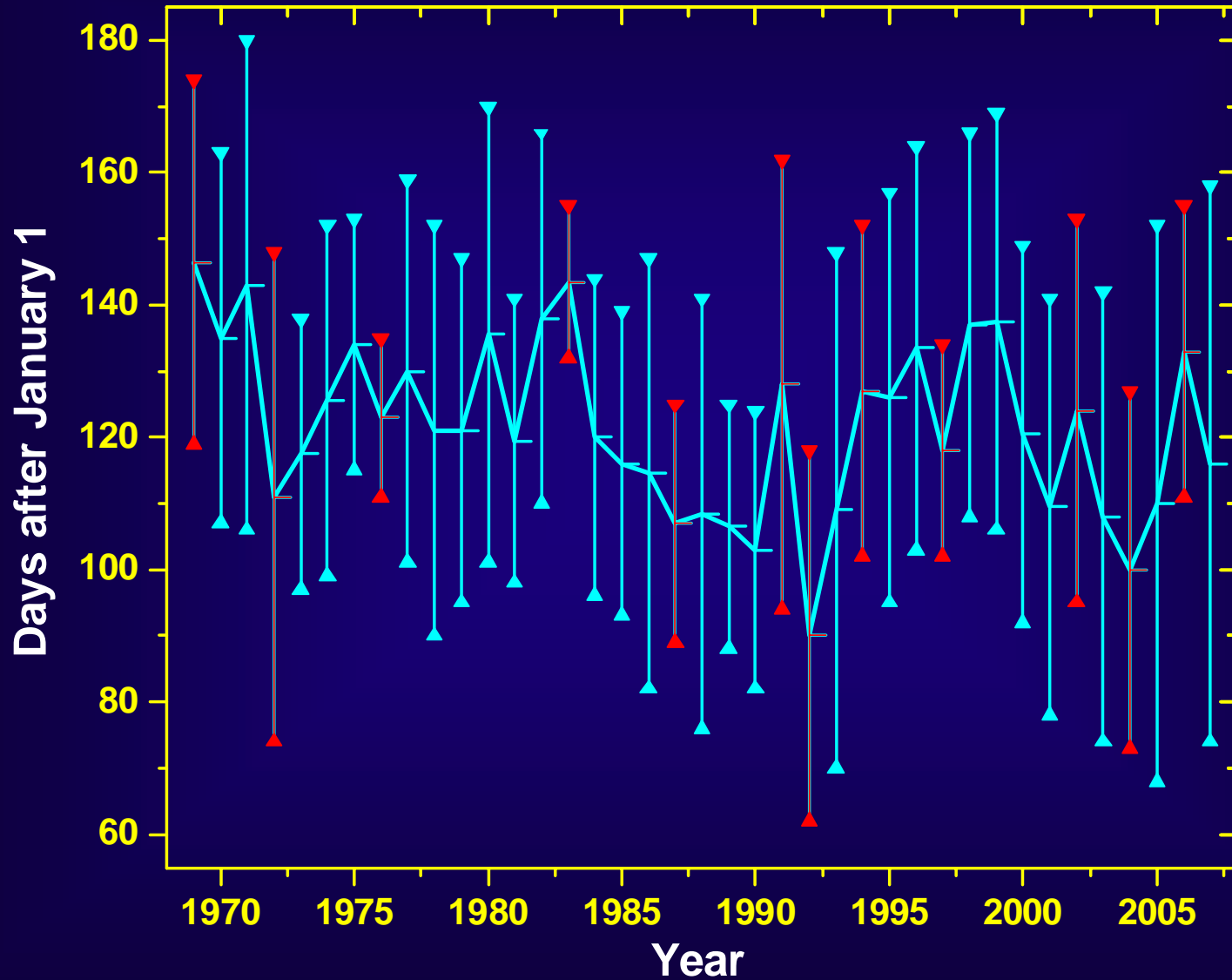
Habitat restriction  
Physiological limitation

DRY WINTERS - Hi X2

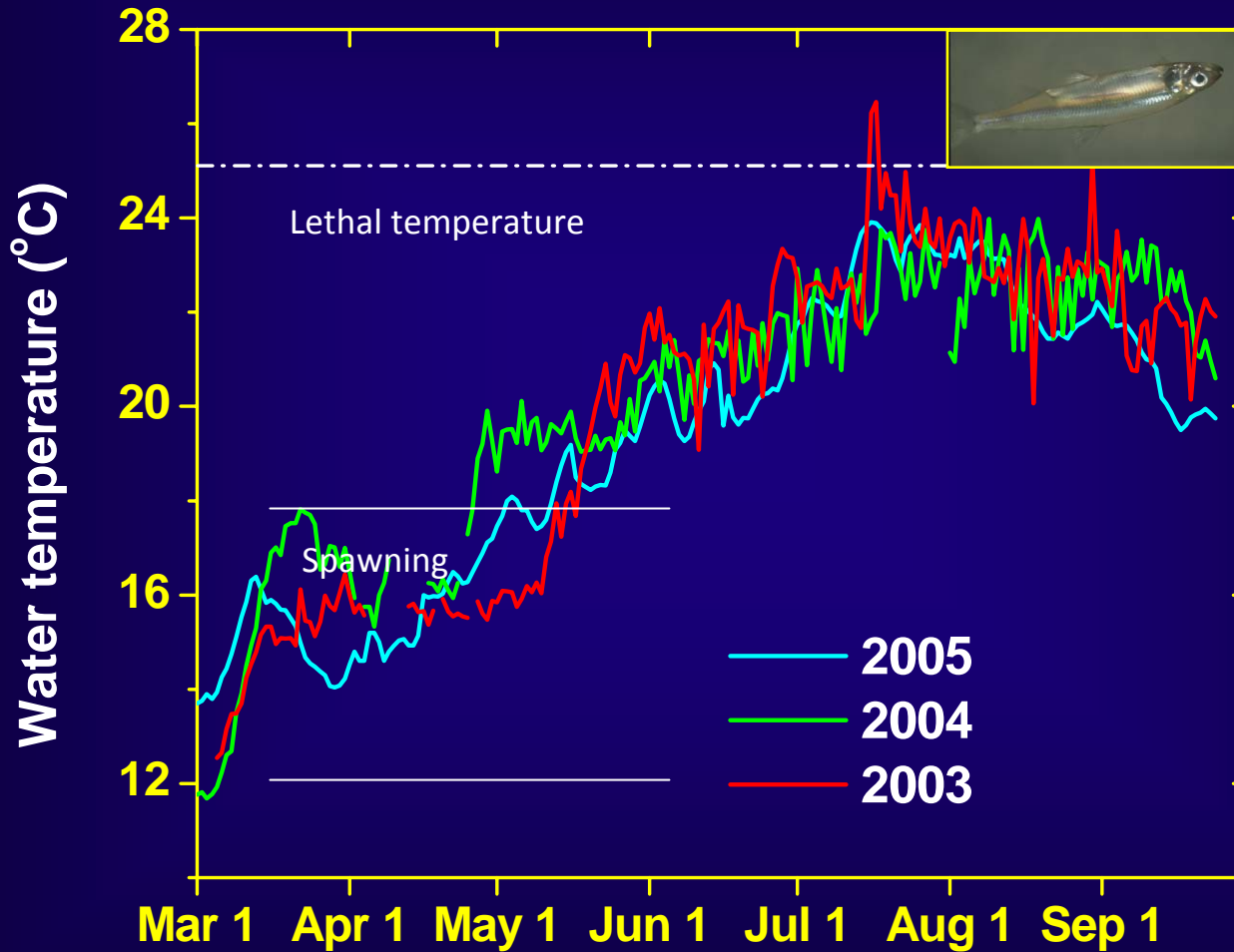
Constraints on spawning  
Low San Joaquin flow  
OMR negative flow



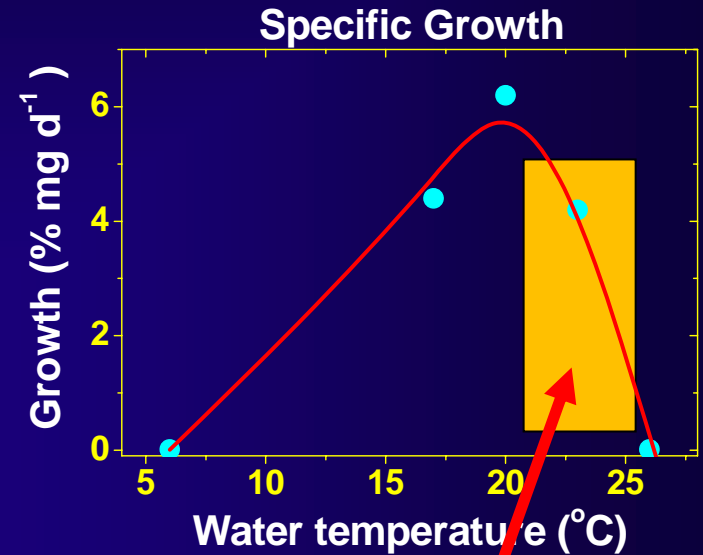
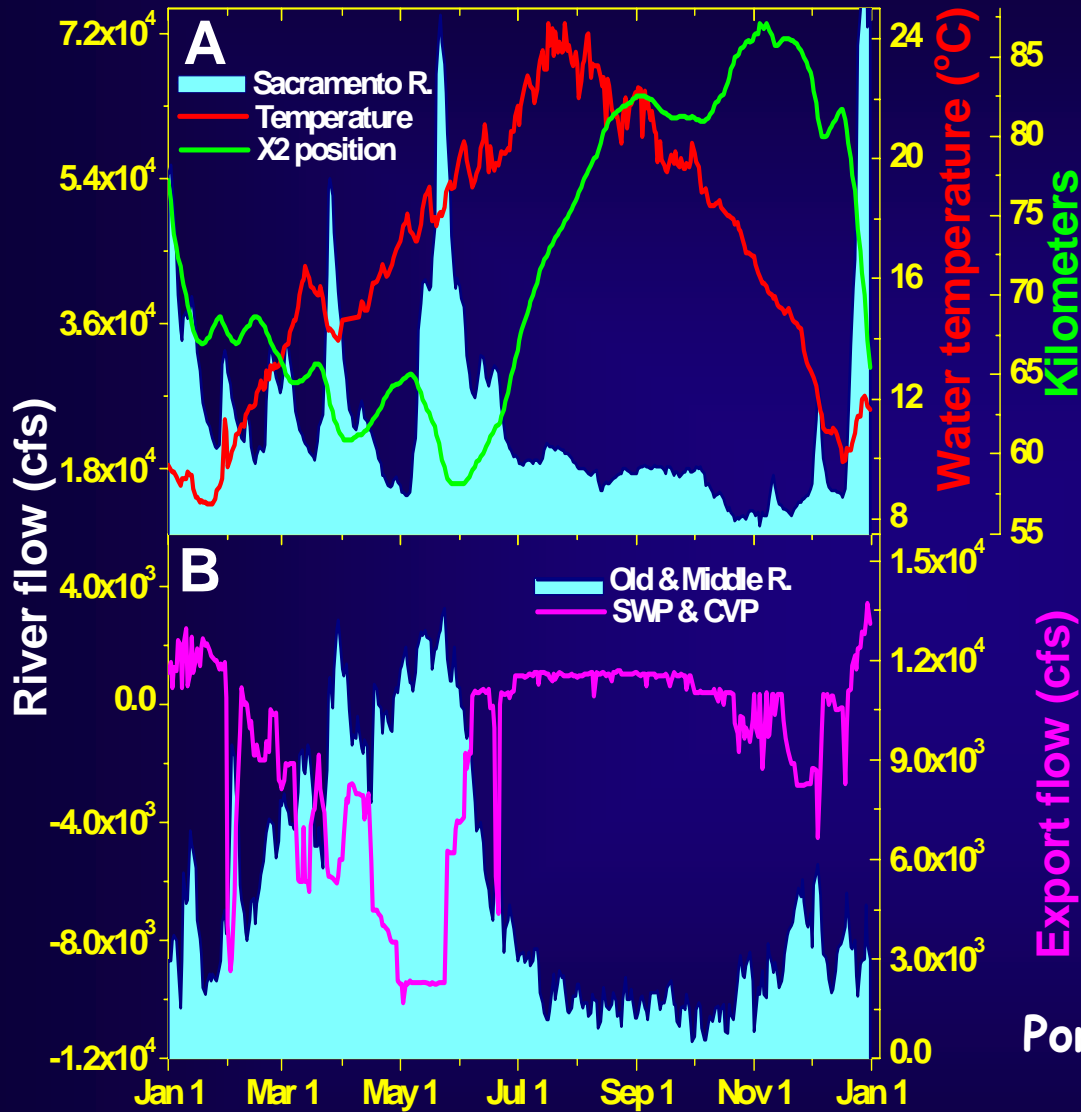
# Climate Change & Constraints on Spawning Season



# Climate Change & Extinction?



2005

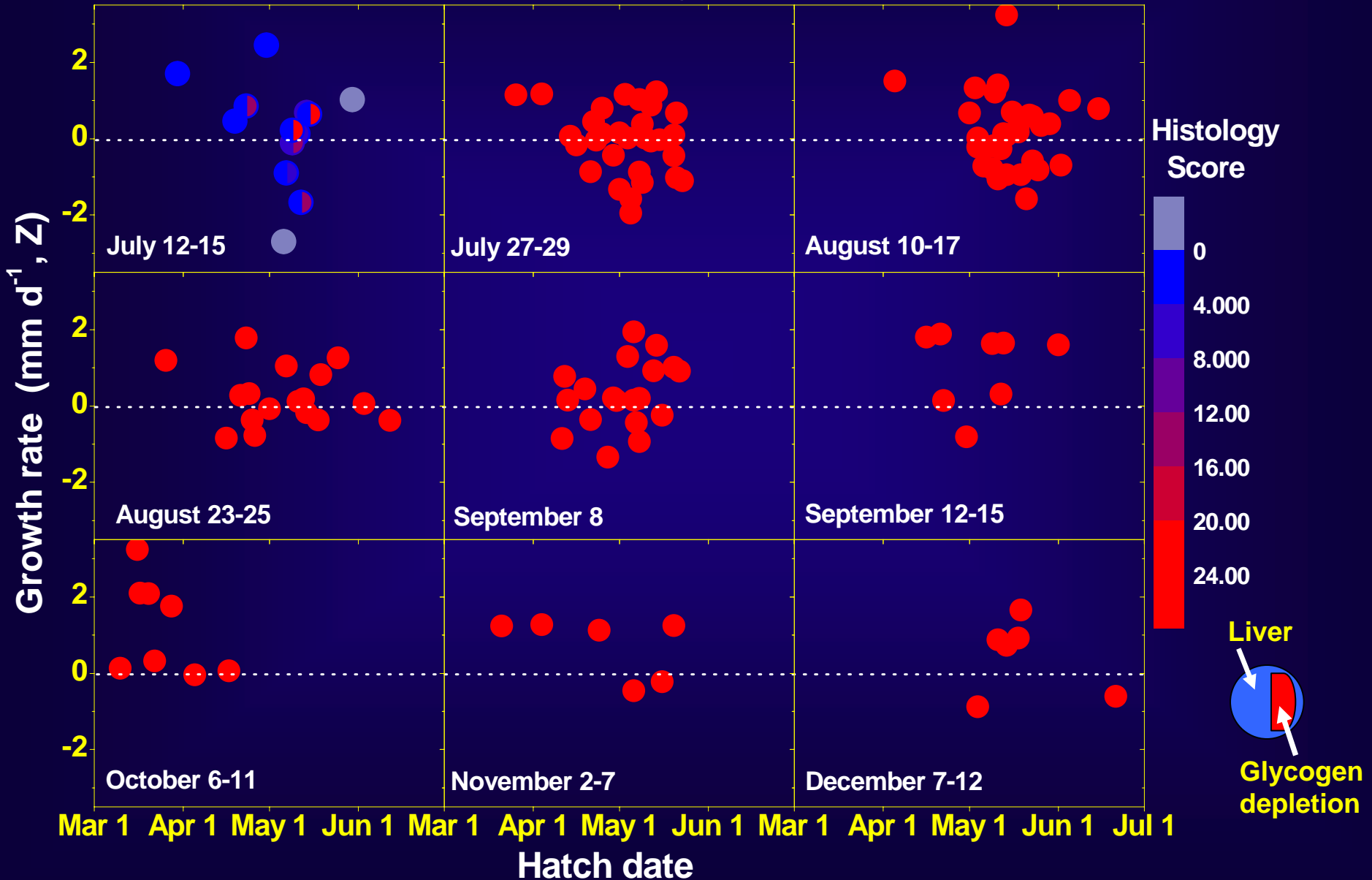


Portner and Knust 2007. Science

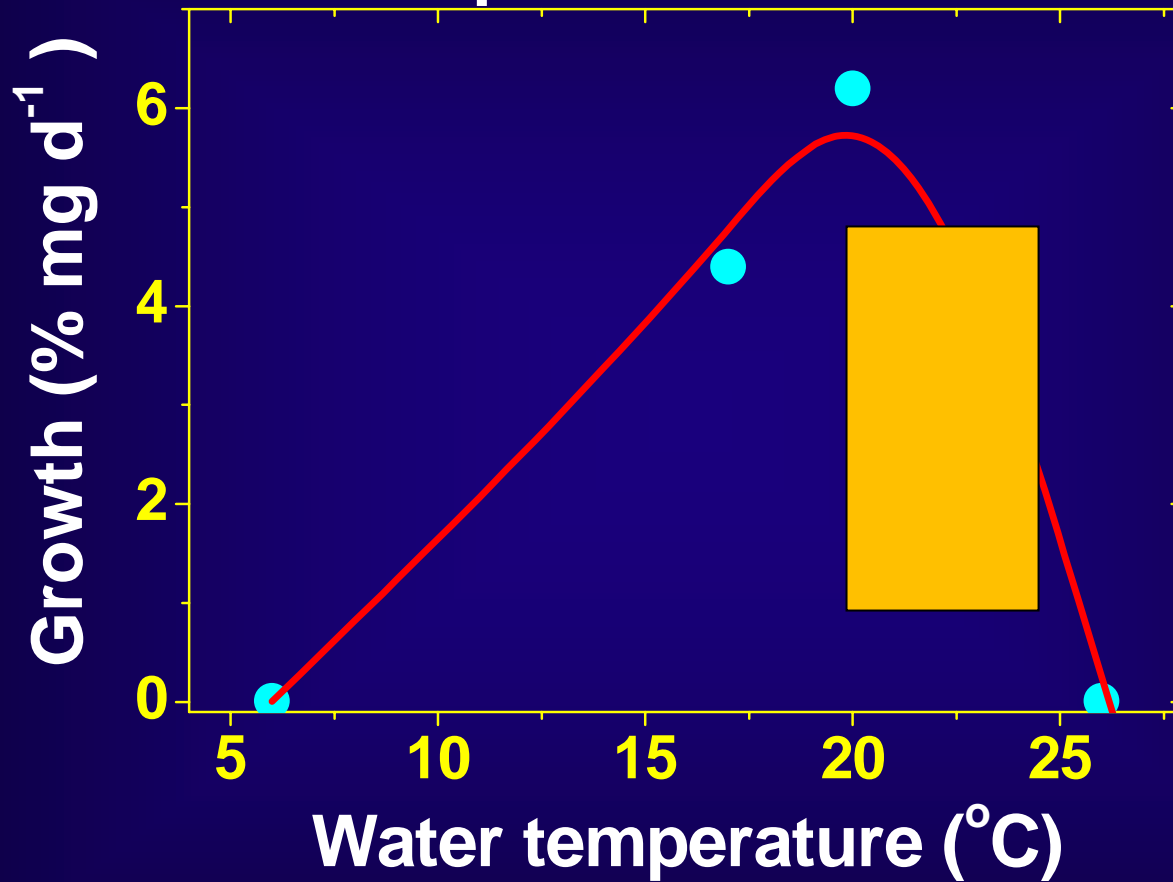
Pejus temperature = turning worse

# Growth Selective Mortality & Histological Condition

Growth Rate from July 5-12, 2005



## Specific Growth





# Take Home Messages:

## Climate Change

- Human perception of large-scale "change".
- Management Mistakes & Surprises
- Different mechanisms at different life stages
- Interacting & Synergistic Effects
- Adaptation (evolve or face extinction)?

"Eskimos are feeling the pinch"

Keith Richards,  
*The Rolling Stones*